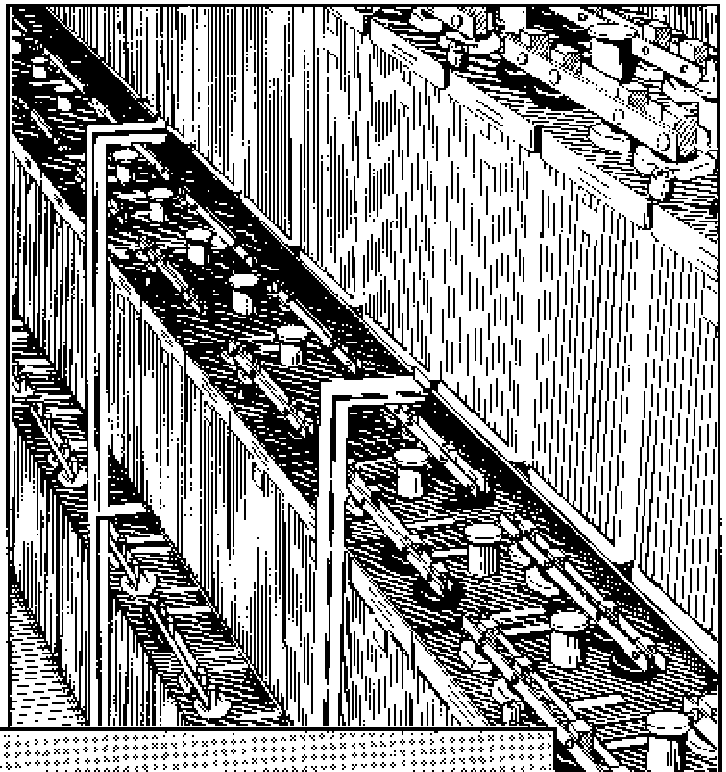
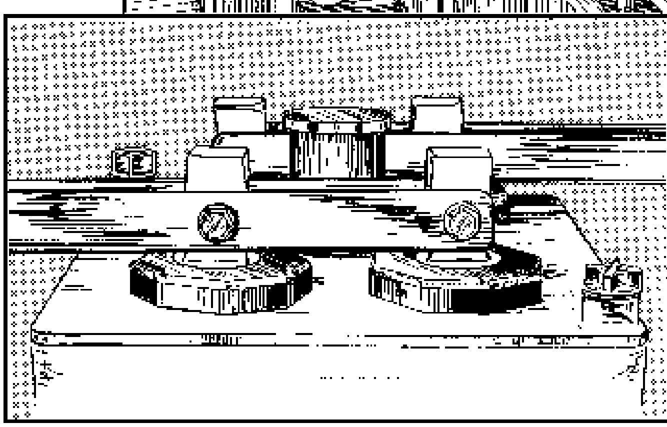
CHAPTER 9
STORAGE BATTERY MAINTENANCE

June 1990





POWER SYSTEM MAINTENANCE MANUAL

WESTERN AREA POWER ADMINISTRATION

STORAGE BATTERY MAINTENANCE

JUNE 1990

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CHAPTER 9

Approved for Publication and Distribution

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Date

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Preface

This guide is issued by the Western Area Power Administration (Western) and is designed to provide specific data, criteria, and recommendations for the safe maintenance and testing of storage battery systems in Western. The procedures and guidelines contained in this document are in accordance with established industry standards and current industry practices. Any corrections or comments concerning this guide may be addressed to the Western Area Power Administration, A6200, Golden, Colorado.

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1. Introduction

The purpose of this chapter is to provide data, criteria, and recommendations for the establishment of an effective and safe maintenance, testing, and replacement program for storage batteries in Western Area Power Administration (Western). The objective of the established program is to realize optimum battery life and to ensure reliable service of the battery system when station service is temporarily lost.

Maintenance and testing procedures are outlined while exact details of some processes are beyond the scope of this chapter. Similarly, Federal environmental and hazardous materials requirements are summarized but not detailed. Recommendations are made based on test results and findings from maintenance and hazard evaluations.

2. Safety

The maintenance and testing of storage battery systems must be performed by trained and experienced personnel who are familiar with the required tools and equipment, as well as the pertinent safety requirements. Only authorized personnel will be allowed to test and to maintain the batteries so that Western may protect untrained personnel and ensure the proper maintenance and testing of the battery system.

2.1 Protective Equipment. When handling, installing, or working with batteries, personnel must wear the following appropriate protective equipment:

- Goggles and face shields
- Protective aprons
- Industrial, gauntlet-type, acid-resistant gloves
- Boots.

2.2 Accidental Contact. Bodily contact with the electrolyte from a battery is dangerous and must be attended to immediately. In case of accidental contact, the following must be available:

- Portable or stationary water facilities for rinsing eyes and skin. Portable eye washers must be properly flushed and refilled with distilled water at least annually to prevent the culture of amoeba.
- A concentrated solution of 5 ounces of boric acid powder to each quart of water must be available to neutralize any accidental splashes of electrolyte from a nickel-cadmium (NiCad) battery on a person or on clothing. A sodium bicarbonate solution (mix 1 pound to 1 gallon of water) should be used for accidental splashes of electrolyte from lead-acid batteries.

2.3 Precautions

- Near the battery, post "NO SMOKING" signs where they are clearly visible to anyone approaching the battery area.
- Do not obstruct battery area exits.
- Do not lay metal objects on top of a battery.
- Avoid wearing metallic objects such as jewelry when servicing or testing batteries.
- Use insulated tools when working around batteries.
- Touch any grounded metal before touching the battery to prevent any sparking caused by static buildup.
- Keep the baking soda or any foreign material from entering the battery cells.
- Install only explosion-proof fixtures in battery rooms. Batteries produce hydrogen gas which cannot be detected by sight or scent.
- Do not perform open-flame activities (such as smoking, torch welding, and so on) in the battery room.
- Provide adequate ventilation in the battery room to prevent the hydrogen gas from reaching a 1 percent volume level in the air.
- Replace the shipping vent plugs on each cell jar with the provided flame arrestors and never remove them.
- Ensure that all connections are kept tight and snug. Observe proper torquing. These measures will avoid possible sparking or excessive heat buildup which can result in battery fires.
- Do not use battery equipment (e.g., hydrometers, thermometers) interchangeably between lead-acid and caustic base (NiCad) batteries. Maintenance equipment should be specifically marked to indicate which type of battery it maintains. Traces of sulfuric acid on NiCad batteries will cause corrosion on the steel plates and containers. Provide a separate supply of distilled water for each battery type.

2.4 Fire Protection

- Fire extinguishers should be readily available for use in the event of a battery fire.
- Battery fire alarms should be incorporated in the alarm system.

3. Maintenance

Each Area Office is responsible for developing and implementing an effective battery maintenance, testing, and replacement program in accordance with the criteria and guidelines given in this document and in accordance with each Area's specific requirements. Western's Headquarters Division of Operation and Maintenance (O&M) (A6200) will provide assistance and guidance upon request.

In addition to researching the applicable standards given in section 7, it is highly recommended that manufacturer's instruction books and data be available at the battery site for reference and use by maintenance personnel.

3.1 Record Keeping Requirements. Data obtained from inspections, tests, and corrective actions must be maintained to document and to monitor the performance of station batteries. A valuable analysis of battery system condition is obtained by tracking maintenance and test statistics over a period of time. To facilitate the proper documentation of battery operation, maintenance, and testing, Western requires that a completed wall battery data card be posted in a prominent location near the battery installation. Appendix B includes battery data card samples and sample forms that can be used to record cell voltages and specific gravity values.

3.2 Maintenance Requirements

3.2.1 Maintenance Intervals. Numerous factors determine regular maintenance intervals for battery and charging systems. These factors include industry standards, manufacturer's recommendations, relative importance of a particular installation, individual battery history, battery age, and gained experience with battery systems.

Depending upon the station, regular inspection intervals vary from 1 week to 3 months. More complete station inspections usually occur every 6 to 12 months. Throughout Western, substations of greater size and importance are usually maintained with greater frequency. The Institute of Electrical and Electronics Engineers, Inc./American National Standards Institute (IEEE/ANSI) standards recommend monthly, quarterly, and annual inspections. Recommended quarterly and annual maintenance includes more thorough inspections as well as load testing to monitor battery integrity.

These recommended schedules should be considered when determining the maintenance intervals for a substation. Many inspection and maintenance schedules for substations within Western consist of monthly and semiannual maintenance procedures. To accommodate such schedules, the recommended quarterly maintenance and inspection might occur semiannually, depending upon the relative importance of the substation to the interconnected power system.

Based upon IEEE/ANSI standards, manufacturer recommendations, and gained experience, the general maintenance intervals shown in table 1 are recommended for storage battery systems in Western's facilities.

3.2.2 Conduction Path. The majority of catastrophic battery failures can be traced to problems within the conduction path of the battery system. The conduction path includes all internal buses, terminal posts, and connecting straps between cells. All connections must remain tightened to manufacturer's recommended torque specifications to avoid sparking or excessive heat buildup, possibly resulting in a battery fire. All connections should be checked for proper torque requirements annually and after a heavy discharge. Cell-to-cell and cell-to-terminal resistances should be checked and recorded after torquing.

Methods for checking resistances include using low resistance ohmmeters or measuring the millivolt drop during capacity testing. Resistance values may vary greatly, from less than 10 micro-ohms to 100 micro-ohms. If significant changes in resistances (20 percent above installation value) occur, or manufacturer's recommended limits are exceeded, workers should take corrective action. Maintenance personnel should refer to manufacturer's recommendations regarding cleaning and re-torquing connections.

Table 1.
Recommended Maintenance Procedures for Storage Battery Systems

Interval	Recommended Maintenance Procedures
Monthly	1. Visually check the general appearance and clealiness of the battery storage system. 2. Check the ambient temperature and condition of the ventilating equipment. 3. Record the float voltage measured at the battery terminals. 4. Record charger output current and voltage. 5. Record pilot cell data: a. Cell voltage. b. Cell specific gravity and electrolyte temperature for lead-acid batteries, corrected for temperature. 6. Check for evidence of corrosion at terminals or connectors. 7. Check for cell cracks and loose connections. 8. Check for evidence of voltage leaks to ground.
Quarterly	1. Perform the recommended monthly maintenance procedures. 2. Check 10 percent of intercell connection resistances chosen at random. 3. Record the voltage of each cell. 4. Record the specific gravity of each cell for lead-acid batteries, corrected for temperature. 5. Record the electrolyte temperature of one out of each six cells chosen at random.
Annually	1. Perform the recommended quarterly maintenance procedures. 2. Tighten all bolt connections to the specified torque requirements. 3. Record all cell-to-cell and cell-to-terminal connection resistances. 4. Perform an integrity test and, if convenient, thermographically scan the battery connections during the test to check for “hot spots.” 5. Verify the accuracy of the charger panel voltmeter. 6. Check the integrity of the battery rack.
Every 5 years	1. Perform the recommended annual maintenance procedures. 2. Perform a capacity test.
Special maintenance	If the battery has experienced abnormal conditions, such as a severe discharge or the age of the battery is nearing its useful life, the maintenance interval should be adjusted accordingly. The maintenance procedures should include as much of or all of the recommended monthly, quarterly, and annual procedures (including performing a capacity test, if necessary).

3.3 NiCad Batteries

3.3.1 General Description. The positive and negative plates are similar in construction, consisting of pockets of perforated nickel-plated steel strips joined to the plate material. The positive plates contain nickel compounds.

The positive and negative plates are insulated from one another by means of hard rubber or plastic separators, which provide mechanical support and prevent excessive dendrite growth. Cells that are furnished in steel containers are mounted in wooden trays, and containers are separated from each other to prevent shorting and to provide ventilation between cells. The vent caps on the cells are spring-loaded to assure a closed position at all times except when the electrolyte is being checked.

A salt formation called potassium carbonate may be found on the top cover of the cells. This formation is non-corrosive and does not damage the battery; however, for the sake of good housekeeping, it should be removed.

A summary of NiCad battery conditions and recommended corrective action is listed in table 2.

3.3.2 Electrolyte. The electrolyte in NiCad batteries is an alkaline solution of potassium hydroxide (KOH) and other added salts having specific properties for battery operation, all dissolved in distilled water.

The freezing point of the electrolyte with a specific gravity of 1.190 is approximately -10°F (-23.3°C). At this point, the solution forms a slush but does not freeze solid. If the battery must operate at temperatures substantially below -10°F (-23.3°C), the specific gravity is usually raised to 1.230 for protection to -40°F (-40°C). However, it is highly recommended that manufacturer's instructions be followed before attempting to change the specific gravity of the electrolyte.

3.3.2.1 Specific Gravity Readings. Specific gravity readings are not usually required as part of the normal maintenance routine for NiCad batteries. Since the electrolyte does not normally enter into the electrochemical charge/discharge reactions, the specific gravity does not change with the state of charge.

3.3.2.2 Electrolyte Level. Caution must be taken when handling the electrolyte. The electrolyte level in all cells should be checked monthly. **The maximum level of the electrolyte is halfway between the tops of the plates and the inside of the cell covers. (DO NOT include vent heights.)** The level can be checked visually if the cell containers are transparent. If not, the level may be determined by first inserting an electrolyte-level test tube (plastic or glass) through the vent until it rests on top of the plates, then placing the finger tightly over the exposed end, and finally withdrawing the tube for inspection. The electrolyte must always be returned to the cell from which it was withdrawn. When the electrolyte level is low, distilled water should be added to restore the electrolyte to the proper level, but the cell should not be overfilled. If the cells are overfilled, the electrolyte will be forced out of the vents during the charging state and will saturate the trays, causing electrolysis between the cells, corrosion of the cell containers, and troublesome grounds in the electrical circuit. Overfilling the cells will dilute the electrolyte to such an extent that the specific gravity will become too weak and the plates will be damaged.

3.3.2.3 Electrolyte Renewal. When the electrolyte is clear and colorless, it is in good condition. An electrolyte that has become contaminated with small quantities of carbon dioxide from the air will form potassium carbonate and will appear cloudy. If the solution becomes colored or cloudy, it is evident that the electrolyte is contaminated with impurities and should be changed.

It may also become necessary to change the electrolyte due to overcharging and overflow which causes the specific gravity to fall outside the manufacturer's specified range. If the specific gravity is weak, a rapid reduction in the life of the battery will follow with continued operation. Therefore, when the specific gravity falls below 1.170, the electrolyte should be changed.

Table 2.
Abnormal Conditions and Recommended Corrective Actions for NiCad Batteries

Abnormal Condition	Recommended Corrective Action
Excessive formation of potassium carbonate	1. Remove the excessive formation of potassium carbonate. 2. Check if the battery is being overcharged. 3. Coat the steel can tops and top hardware with acid-free petroleum jelly (e.g., Vaseline) after cleaning the carbonate salts.
Corrosion through electrolysis of the cell containers	1. Keep cells and trays clean and dry at all times. 2. Never place or drop any metal articles between the cells. 3. If the supporting racks include metal pans, the pans should be provided with drain holes to prevent moisture collection. 4. Cell containers must not be grounded.
Corrosion through contamination from sulfuric acid	1. Provide separate tools and utensils for servicing the NiCad batteries. Since small traces of sulfuric acid can ruin a NiCad battery by attacking and corroding its steel plates and cell containers, never use any tools or utensils such as hydrometers, funnels, rubber hoses, battery filters, etc., which have been used at anytime for servicing lead-acid batteries. 2. Provide a separate supply of distilled water that is used only for NiCad batteries.
Contaminated stored electrolyte	1. Store the electrolyte in airtight, clean containers made out of iron, steel, glass, or porcelain to prevent the absorption of carbon dioxide from the air which in turn forms potassium carbonate (this will temporarily lower the capacity of the battery when used).
Slushed electrolyte	1. The electrolyte with a specific gravity of 1.190 forms a slush if the battery is operated at temperatures substantially below -10°F (-23.3°C). Therefore, the specific gravity is usually raised to 1.230 for protection to -40°F (-40°C). Follow manufacturer's instructions before attempting to change the specific gravity of the electrolyte.
Contaminated electrolyte in cells	1. Always return the electrolyte to the cell from which it was withdrawn during inspection. 2. **DO NOT** overfill the cells with distilled water. 3. If the electrolyte solution becomes colored or cloudy, it is evident that the electrolyte has become contaminated with impurities. 4. If the specific gravity falls below 1.170, the electrolyte should be changed.
Abnormal conduction paths	1. Tighten all connections to manufacturer's recommended torque specifications to avoid sparking or excessive heat buildup. 2. Check all connections after a battery experiences a heavy discharge. 3. Check cell-to-cell and cell-to-terminal resistances after torquing the connections.

Workers must follow manufacturer's instructions when preparing renewal electrolyte. After the renewal electrolyte solution of proper specific gravity has been prepared and cooled, the change of electrolyte in the cells is made by performing the following steps:

(1) Discharge the battery to 0.8 volts or lower (per cell).

(2) Pour the electrolyte out of the cells into a container and rinse the cells with clear distilled water. The old electrolyte must be disposed of in accordance with Federal and State regulations.

(3) Fill the cells with the renewal electrolyte to the proper level.

(4) Charge the battery at the booster charge rate until it is fully charged (refer to section 3.3.3 for more information).

3.3.3 Charging. Generally, specific gravity or cell voltage readings cannot determine the state of charge of a NiCad battery. The battery should be given a booster charge once a month, after any heavy or intermittent discharges, or after the battery charger has been out of service to ensure that the battery is fully charged. Maintenance personnel should maintain a record of the monthly booster charges. The accuracy of the charger voltmeter should be checked against an accurate voltmeter at least once a year. A summary of charging requirements of NiCad batteries is given in table 3.

Table 3.
Charging of NiCad Batteries

Charge	Requirements
Initial charge	1. The first charge of batteries that are delivered discharged should be carried out at constant current. 2. When the charger maximum voltage setting is too low to supply constant current charging, divide the battery system into two parts to be charged individually. 3. Follow the manufacturer's instructions for setting the charging rates.
Float charge	1. Float charge voltage should be maintained at 1.43 V to 1.45 V per cell to avoid gassing. 2. Maintain constant voltage charging to prevent the battery from discharging at a depressed voltage level. 3. Avoid charging the battery at higher values than recommended to prevent excessive water consumption.
Booster charge	1. The booster charge should be 1.65 V per cell. 2. A fully discharged battery in good condition can be fully charged in four hours. 3. If the float charge has maintained the battery in a fully charged condition during the month, the monthly booster charge will be minimal. 4. The booster charge should be continued until the charging current has leveled off for two consecutive readings one-half hour apart. 5. When applying a booster charge, it is important to watch the electrolyte temperature in the cells. If the temperature reaches 100°F (43.3°C), the charging rate should be reduced at once.

3.3.3.1 Float Charge. Float charge voltage is normally maintained at 1.43 to 1.45 volts per cell to avoid gassing. Evolution of gas begins at about 1.47 volts. Continuous operation at this level should be avoided since water consumption may become excessive. A low floating voltage may produce excessive voltage variations between cells which will cause the battery to become partially discharged. In such cases, the charger voltage setting should be increased within the above limits.

3.3.3.2 Booster Charge. The booster charge level should be 1.65 volts per cell (approximately 152 volts on a 92-cell bank). A fully discharged NiCad battery in good condition can be fully charged in 4 hours, provided the battery charger has the capacity to provide the current taken by the battery at the beginning of charge. As the battery approaches full charge, the charging current drops off and the voltage stabilizes at the voltage where the charger is set. The battery charger then stabilizes at a new float condition represented by no further increase in the voltage at the battery terminals and no further decrease in the current rate going to the battery. **If the float charge has maintained the battery in a fully charged condition during the month, the monthly booster charge will be minimal.** The booster charge should be continued until the charging current has leveled off for two consecutive readings one-half hour apart. When applying a booster charge, workers should watch the electrolyte temperature in the cells. If the temperature reaches 110°F (43.3°C), the charging rate should be reduced at once.

3.4 Lead-Calcium Batteries

3.4.1 General Description. A charged cell, whether of the pasted or formed type, consists of brown lead peroxide on positive plates, and gray sponge lead on negative plates submerged in a sulfuric acid solution electrolyte. On discharge, the electric current converts the active materials of the positive and negative plates to form lead sulfate through the chemical reaction of sulfuric acid. The lead sulfate is white in color but cannot be seen on the plates unless the cell is overdischarged. Initially, this makes the plates lighter in color. Heavy or prolonged discharge makes the plates appear entirely white. Charging the cell reverses this process, converting the lead sulfate on the plates to lead peroxide and producing sulfuric acid. As the charging process nears completion and little lead sulfate remains to convert, the charging current begins to separate the water into two gases, oxygen and hydrogen, which bubble to the top of the electrolyte to form a mixture of gases. This mixture of gases is considered very explosive, and extreme caution must be exercised when handling the electrolyte.

A summary of lead-calcium abnormal conditions and recommended corrective actions is listed in table 4.

3.4.2 Electrolyte. The sulfuric acid electrolyte solution is highly corrosive and must be handled with extreme caution. Contact with the skin or eyes is dangerous and can cause severe burns.

During recharging, high specific gravity electrolyte is produced. This acid will sink to the bottom of the cell, resulting in a specific gravity gradient throughout the height of the cell. The specific gravity reading at the top of the cell may be lower than the cell's actual specific gravity. After charging, diffusion will correct this gradient.

3.4.2.1 Specific Gravity Readings. Specific gravity values are based upon a temperature of 77°F (25°C). The temperature of the electrolyte must be recorded at the time the specific gravity readings are taken. (The electrolyte temperature may vary considerably from the temperature of the room in which the battery is located.) The specific gravity readings must be corrected for the actual electrolyte temperature. One point (0.001) is added for each 3°F (1.67°C) above 77°F (25°C). One point is subtracted for each 3°F below 77°F (25°C).

The electrolyte level should also be recorded at the time specific gravity readings are taken. The specific gravity of a cell will increase with decreasing electrolyte level due to water evaporation or electrolysis. Manufacturer's data will provide correction factors to specific gravity readings for varying levels.

Hydrometer floats vary considerably, so it is recommended that the float be calibrated periodically to ensure correct readings especially when looking for a trend over a period of years.

3.4.2.2 Electrolyte Level. The electrolyte level depends upon the charging rate since the electrolysis action during charging expands the electrolyte. Therefore, the electrolyte may appear higher than the high level line. This is not an objectionable condition. However, preferably the level is read after the battery has been at one float charge level for at least 72 hours. Distilled water is added only when the level is at the low level mark. Typically, this should occur no more than every two or three years for a healthy battery.

Table 4.
Abnormal Conditions and Recommended Corrective Actions for Lead-Calcium Batteries

Abnormal Condition	Recommended Corrective Action
White appearance of plates	1. Properly charge cell.
Formation of oxygen and hydrogen	1. Exercise extreme caution when handling the electrolyte. The mixture of these gases is considered very explosive. 2. Provide adequate ventilation.
Excessive water loss	1. Normally water should be added when the level approaches the low level mark which is every two to three years. However, to retard excessive water loss, add a thin layer (usually one-quarter inch deep) of pure mineral oil on top of the electrolyte.
Over-sulfation of battery plates and cells	1. Prolong the proper charging to correct the oversulfation on the negative plates. 2. The positive plates, unless severely buckled or cracked, will not be repaired by removal of sulfate but may continue to be used as long as they retain satisfactory ampere-hour capacity. 3. Check for external and internal grounding. 4. In cases where one or more individual cells become over-sulfated while the balance of the battery cells is in good condition, the oversulfated cells should be treated separately. It is better to remove them from the circuit. 5. Charge the cell fully until the specific gravity stops rising. Record specific gravity readings at 3- to 5-hour intervals to determine when the specific gravity stops rising. 6. Add water as a last resort where prolonged charging at normal specific gravity does not remove the sulfate from the negative plates. Follow manufacturer's recommendations when adding water to the electrolyte.

3.4.2.3 Oil Use in Battery Cells. To retard water loss from evaporation and electrolysis, some manufacturers recommend floating a thin layer (usually one-quarter inch deep) of pure mineral oil on top of the electrolyte. Refer to the manufacturer's recommendations regarding oil use in battery cells.

3.4.2.4 Specific Gravity Adjustment. Adjustments of specific gravity should never be undertaken until workers establish that the gravity is outside acceptable limits and until all cells have been given an equalizing charge so that the true measure of this error will be known. In preparing for a change of gravity, workers should bring the electrolyte to the marked level or make an allowance for this type of error. The hydrometer readings should be corrected for temperature, as detailed in section 3.4.2.1. Before adjusting for low gravity, workers must ensure that the gravity cannot be raised. This precaution is made by continuing the equalizing charge until the specific gravity shows no rise, and then continuing the charge for 3 more hours.

Workers should never make a gravity adjustment on a cell that does not gas on charge. Pure 1.300 specific gravity sulfuric acid should be ready for use. Some electrolyte is then removed from the cell and replaced with the 1.300 specific gravity sulfuric acid. The battery is charged again until all cells gas for an hour; then, if the specific gravity is not normal, the adjustment is repeated. This same method is used to lower the specific gravity, but some of the electrolyte is replaced with distilled water. Sulfuric acid with a 1.300 specific gravity consists of 30 percent concentrated acid and 70 percent distilled water by volume.

3.4.2.5 Sulfation. If battery charging is neglected, the sulfate accumulates and fills the pores of the plates, making the active material dense and hard. This condition is ordinarily referred to as "oversulfated."

The normal lead sulfate formed on discharge of the battery is in a form that absorbs the charge very readily. When a battery is oversulfated, the plates are less porous than normal, and absorption of the charge is difficult. The ordinary charge is insufficient to reconvert all of the sulfate to sulfuric acid; consequently, the specific gravity remains below normal.

The active material of oversulfated negative plates is generally light in color, either hard and dense or granular and gritty, and easily disintegrated. The negative plates require the prolonged charge necessary to restore an oversulfated battery. Oversulfated positive plates, unless physically disintegrated or badly buckled, undergo little change in general appearance. Removing sulfate will not restore buckled or cracked positive plates. But these plates may continue to be used as long as they retain satisfactory ampere-hour capacity. An individual cell may become oversulfated by external grounding, by an internal short circuit, or by drying out.

When the specific gravity of the electrolyte will rise no higher after continued charging, it shows that there is no more sulfate to be converted to acid, since the electrolyte receives acid from only the plates.

3.4.2.5.1 Evaluation of Oversulfation. If a battery or cell appears to be oversulfated, it should be charged fully until the specific gravity stops rising. Then, one of the cells in the poorest condition should be discharged at the 8-hour rate to a final voltage of 1.75 volts. If it follows the manufacturer's normal capacity curve, from approximately 100 percent rated capacity for a fairly new battery down to 80 percent of its initial rated capacity for a battery close to the end of its expected life, then the reason for apparent oversulfation should be sought elsewhere, such as leakage paths to ground. If acceptable capacity is not obtained, the plates (which may be oversulfated) should be treated carefully.

3.4.2.5.2 Treatment of Oversulfation. In cases where one or more individual cells have become oversulfated while the balance of the battery is in good condition, the oversulfated cells should be treated separately. It is better to remove them from the circuit. Oversulfated plates should be handled as little as possible.

To begin this process, the battery or cells are recharged. When it is considered fully charged, the hydrometer reading of each cell and the temperature of several cells are recorded. The battery is then charged at a rate as near one-half its normal 8-hour ampere rate as the charging equipment will permit. If the electrolyte temperature reaches 110°F (43.3°C), the charging rate is reduced.

Hydrometer readings should be recorded at 3- to 5-hour intervals to determine the specific gravity rate of change. The charge is continued, and the readings are recorded until there is no further rise in any cell during a period of at least 10 hours. To maintain the level of the electrolyte at a constant height, water is added after each reading. If water is added just before taking hydrometer readings, the water would not have time to be mixed with the electrolyte by the gassing that results from charging.

3.4.2.5.3 Water Treatment for Oversulfation. If recharging as described does not produce the desired results, a water treatment is recommended. (Note: The water treatment should be attempted only as a last resort where prolonged charging at normal specific gravity would not eventually remove the sulfate from the negative plates. The water treatment removes it thoroughly and in much less time.) The water treatment includes:

- Reducing the specific gravity of the electrolyte until it is approximately 1.050 to 1.100;
- Charging at one-half the normal 8-hour current rate to both a 10-hour specific gravity maximum and a 10-hour voltage maximum. If the specific gravity rises to 1.150, the electrolyte should be removed and replaced with distilled water to lower the specific gravity to a range from 1.050 to 1.100. This step should be repeated

until the maximum specific gravity obtained by charging is below 1.150; and then

- Increasing the specific gravity by adding electrolyte and by charging at the normal 8-hour current rate until the specific gravity stabilizes for 3 hours at the normal operating value.

3.4.3 Charging. Prolonged undercharging will cause the battery plates to sulfate and may result in a permanent loss of capacity. Prolonged overcharging results in excessive gassing, water consumption, sedimentation, and shortened life span.

The battery should be recharged as quickly as possible following heavy discharge. This can be done by temporarily raising the charging voltage to the maximum allowed by the other circuit components (not to exceed the range of 2.33 to 2.38 volts per cell). The battery charging system should be returned to its normal voltage after the battery becomes fully charged.

A summary of lead-acid storage battery charging requirements is listed in table 5.

Table 5.
Charging of Lead-Acid Storage Batteries

Charge	Requirements
Initial charge	1. An initial charge upon installation is not required because the battery will automatically receive the initial charge at float voltages. 2. After about 2 weeks, initial cell voltages and specific gravity readings should be recorded.
Float charge	1. Floating current required to keep lead-calcium cells at full charge is in the order of one-fourth to one-third of what lead-antimony cells need, but it is usually necessary to float lead-calcium cells at a slightly higher voltage. 2. For a typical 60-cell lead-calcium battery floated at 2.17 volts per cell and equalized at 2.33 volts per cell, the normal voltage range would be 130.2 to 139.8 volts.
Equalizing charge	1. The purpose of the equalizing charge for lead-antimony and lead-calcium cells is to ensure: a. Every plate in every cell is brought with certainty to a state of full charge by a reasonable overcharge. b. Every cell gasses freely. c. All cells gas at approximately equal rates. d. The specific gravity of all low cells has stopped rising. 2. An equalizing charge should be given: a. If any trouble is suspected. b. If too little water replacement is being made, c. If the battery has stood long with only a partially full charge. d. After a heavy demand on the battery which nearly drains it of energy. 3. Manufacturer's recommendations regarding the proper charging rates should be observed for optimum battery performance and life.

3.4.3.1 Initial Charge. An initial charge upon installation is not required because the battery will automatically receive the initial charge at float voltages. After about 2 weeks, initial cell voltages and specific gravity readings should be recorded. If circumstances exist for the initial charge at a faster rate, the battery may be charged for a few days at 2.33 to 2.38 volts per cell (connected equipment permitting).

3.4.3.2 Float Charge. For a typical 60-cell, lead-calcium battery floated at 2.17 volts per cell and equalized at 2.33 volts per cell, the normal voltage range would be 130.2 to 139.8 volts. Lead-calcium batteries may not require equalizing if floated between 2.2 and 2.25 volts per cell. This would give a 60-cell battery a voltage between 132 and 135 volts. Lead-calcium batteries, therefore, have a distinct advantage over other types of batteries when constant voltage is desirable.

3.4.3.3 Equalizing Charge. An equalizing charge is a short-term charge at a voltage greater than the float voltage. This equalizing charge ensures that the cells remain fully charged and that all cells are at the same voltage. The equalizing charge will also help to prolong battery life.

Equalizing charges are normally applied for 36 to 72 hours or longer, depending upon the manufacturer's recommendations. These charges are applied at intervals no greater than 18 months. More frequent equalizing charges may be necessary under the following conditions:

- If the specific gravity, corrected for temperature, of any one cell is 10 points (0.010) below the average of all cells at the time of inspection;
- If the average specific gravity for all cells has fallen 10 points from the average installation value;
- If any cell voltage falls below 2.13 volts; if this occurs, an equalizing charge should be applied immediately.

3.4.3.4 Voltage Readings. The main purpose for reading no-load voltages is to determine whether or not an equalization charge is required. Manufacturer's recommendations regarding charging rates should be observed for optimum battery performance and life. Charging levels may be adjusted up or down to correct capacity, gassing, electrolyte level, and other problems.

Monthly inspections include recording the charger voltmeter to determine if the battery is being floated at the proper voltage. Workers should adjust the battery charging voltage when necessary and check voltages when the power or station service transformer taps are changed. During quarterly inspections, workers should record all cell voltages and total battery voltage. The accuracy of panel voltmeters should be checked annually.

3.5 Gel-Type Batteries

3.5.1 General Description. In normal use, the gel-type batteries will not generate or release hydrogen gas, will not release acid mist, and will not leak acid, provided the cells are not damaged, misused, or abused.

The batteries can be mounted in modular racks in a vertical, vertical-stacked, or horizontal-stacked position. In all instances, they must be insulated from ground to minimize the hazard of electrical shock. Insulating pads are normally provided with the batteries to insulate the modules from ground and to minimize the electrical shock hazard. Western recommends that the modules not be grounded.

All modules, regardless of layout configuration, should be spaced 4 inches by 1/8 inches apart to provide electrical isolation. Wider spacing decreases the performance of the battery.

The cell covers should be cleaned periodically with a water-dampened cloth to remove dust, checked for any dampness caused by the electrolyte, or inspected for any signs of corrosion. If corrosion is present, workers should disconnect the connector from the terminal and gently clean the area using a suede brush or #00 grade sandpaper. Then a thin coat of No-OX-Id "A" grease should be applied to the cleaned contact and the cable reconnected to the terminal.

3.5.2 Electrolyte. The electrolyte in the gel-type battery cells contains sulfuric acid. If the safety vent opens while the explosive gases are being generated (e.g., in the event of a charger malfunction), these explosive gases will be released. The electrolyte can withstand extended partial state charge operation at reduced capacities. It also can tolerate low ambient temperature levels. Ambient temperatures of 75°F (24°C) to 77°F (25°C) will result in optimum battery life. High ambient temperatures will reduce battery life.

3.5.3 Ventilation. Under normal recommended charging, the battery does not vent any gases. When the battery is excessively overcharged, hydrogen and oxygen can be generated. Tests have confirmed that 99 percent of these gases are recombined in the cell. Normally, special ventilation is unnecessary; however, the battery should not be installed in an airtight room. The battery can be stored in the same room as the rest of the equipment.

3.5.4 Charging. The state of charge of the battery can be determined approximately by the amount of charging current going into the battery if the connected load is constant. Initially, the charging current, read at the charging ammeter, is a combination of the load current plus the current charging the battery. The current charging the battery will decrease and eventually stabilize when the battery is fully charged. A constant current level for three consecutive hours reflects a state of charge of 95 to 98 percent.

If the connected load is variable, the battery voltage is monitored. If the voltage across the pilot cell is stable for six consecutive hours, the battery is 100 percent charged.

3.5.4.1 Initial Charge. Initial charge is not required if the battery has been in storage for less than 6 months from date of shipment to initial startup. Otherwise, constant voltage is the only charging method. The recommended maximum is 2.35 volts per cell; charging at this rate takes 12 hours. Charging at 2.30 volts takes 24 hours. To perform the initial charge in the shortest time, technicians should select the highest voltage the system allows.

3.5.4.2 Float Charge. Recommended float voltages range from 2.25 to 2.28 volts per cell. The maintenance worker should select any volts-per-cell value within the range that results in a series string with an average volts per cell equal to that value.

3.5.4.3 Recharge. Following a discharge, all batteries should be recharged as soon as possible. To do this as quickly as possible, the charger output voltage is raised to the highest value that the connected system will permit.

3.5.4.4 Equalizing Charge. Under normal conditions, equalizing voltages are not required. Nonuniformity of cells can result from a low float voltage due to improper adjustment of the charger, a panel voltmeter that is reading an incorrect output voltage, or variations in cell temperatures greater than 5°F (2.78°C). Equalizing voltages should be given if the float voltage of the pilot cell is less than 2.20 volts per cell or more than 0.04 volts per cell below the average of the battery, if the individual cell voltages show an increase in spread since the previous quarterly readings, or if a yearly check of all cell voltages reveals a difference of 0.04 volts between any cell and the average cell voltage. To equalize a charge, workers should use a charging voltage higher than the normal float voltage for the same number of hours as the initial charge table determined by the voltage used. The battery is fully charged when the current (or voltage, depending on the load) stabilizes.

4. Testing

The objective of battery testing is to ensure that the battery system can store the required energy and deliver it efficiently when the need arises. A capacity test can evaluate the battery's ability to store the required energy and deliver constant current over extended periods, whereas an integrity test can determine whether internal battery deterioration or connection path problems (such as corrosion) would prevent the energy's efficient delivery.

4.1 General. Periodic battery inspections only require specific gravity readings, no-load voltage readings, temperature measurements, and visual inspections. None of these can detect most of the capacity deficiencies nor the connection problems that may develop within a battery system. Appendix A lists recommended equipment to perform reliable capacity and integrity tests.

As a supplement to periodic inspections, IEEE/ANSI standards recommend that maintenance personnel perform periodic load testing to help discover and identify degradation and conduction path problems.

4.2 Load Testing. There are two major reasons for load testing a battery: to determine the capacity of the battery, and to determine the integrity of the battery. The battery capacity test is necessary at least every 5 years, until the battery starts showing signs of degradation or has reached 85 percent of its life expectancy. Then it should be performed every year. Sufficient degradation in capacity to warrant annual capacity testing varies among battery types:

- NiCad batteries: a drop in capacity in excess of 1.5 percent per year of rated capacity from the previous capacity test.

- Lead-calcium batteries: a drop of 2 percent per year in capacity from the previous capacity test, or the capacity is below 90 percent of the manufacturer's rating.

- Gel-type batteries: the intervals between battery capacity tests are left to the discretion of the maintenance personnel. Although no drop in battery capacity should occur during the lifetime of the battery, a battery capacity test should be performed at specific intervals as a part of the routine maintenance of the battery system or as abnormal conditions warrant.

An integrity test should be performed on a regular basis, ranging anywhere from quarterly to annually, depending upon the relative importance of the substation to the interconnected power system. An integrity test subjects the battery to the normal service current while measuring voltage levels within the battery system.

To detect the conduction path deficiencies described in section 3.2.2, it is only necessary to subject the battery to momentary load, since the voltage drops created by conduction path problems will appear instantaneously, indicated by sparking or by overheated connectors.

Appendix A includes information on recommended load testing equipment.

4.2.1 Test Conditions. To obtain valuable test results which may be used to track battery performance over a period of years, the status of the station's direct current system must be the same each time the battery is tested. Maintenance personnel should record all data (such as the charger voltage setting, charging current, electrolyte temperature, and specific gravity) before each test.

Workers must ensure that other systems or equipment that are dependent upon the battery system are not jeopardized by the load tests. Workers should take adequate precautions by disconnecting the battery bank from the charger and isolating the battery from critical loads. Finally, the workers must inform parties that may be affected by the tests (such as the control center), and log the testing activity in the substation log book.

4.2.2 Acceptance Testing. The user or the manufacturer should conduct an acceptance test for battery capacity at the time of installation. For comparative purposes, Western recommends that the periodic load tests be conducted under the same conditions as the acceptance test if the acceptance test is conducted after installation. Thus, the resulting battery capacity will mirror all conditions affecting the battery — maintenance, environment, design, manufacturing quality control, charging, etc. Values obtained from load tests and inspections are compared to manufacturer's data and graphs. Battery system deficiencies as well as life expectancy and performance can in this way be closely tracked.

4.2.3 Capacity Testing. The single most important criterion used to determine whether or not to replace a battery is the capacity. Both battery manufacturers and the existing industry standards recommend a battery be replaced if it fails to **deliver 80 percent of rated capacity.** At this point, the capacity of a battery falls sharply as a function of time. The only accurate and accepted method for determining the capacity of a battery is a discharge test measuring the amount of energy removed from the battery.

The battery capacity is measurable and frequently expressed as a percentage. This percentage is derived from the ratio of the actual time to nominal time for the battery to discharge to a given final test voltage. The critical element in this test is to have the capability to control the test, be able to repeat it, and accurately record the battery's behavior down to the cell level. Only in this way can changes in battery performance be tracked over time or a problem pinpointed.

The capacity tests require a constant current to accurately determine the battery capacity. Capacity test duration should be equal to the duty period for which the battery was sized (i.e., at the 8-hour rate). Frequently factory ratings are provided in ampere-hours; these ratings must be converted to amperes by dividing by the hours of test duration.

4.2.4 Calculating Battery Capacity. Battery and cell capacity (temperature corrected) are determined by utilizing the acceptance or performance test data in the following equation:

$$\%\ \text{Capacity} = \frac{\text{Amp Hour (Test)}}{\text{Amp Hour (Acceptance)}} \times 100\ .$$

In all cases, the discharge current should be corrected for temperature. The manufacturer's rated discharge current is divided by the correction factor "K" found in table 6 according to the measured pretest electrolyte temperature. This number is then compared to the actual discharge current measured during the test.

4.2.5 Capacity Test Procedure. To prepare for the discharge at the temperature corrected rate, a constant current load unit is set up with ammeter, voltmeter, and timer.

(1) Start the test by connecting the test load and begin timing.

(2) Stop the test when the battery terminal voltage drops to the predetermined final test voltage (the final volts per cell multiplied by the number of cells).

(3) Measure and log all the cell voltages and the overall battery voltage at the terminals. At least three sets of measurements under load should be taken at the beginning, end, and specified intervals. (NOTE: Such cell measurements should include the interconnection. They are made by measuring the voltage between cell posts of like polarity, e.g., the (+) of cell No. 1 to (+) of cell No. 2).

(4) To avoid the reversal of cell polarity, a cell should be removed from the battery as it approaches 1 volt. The test should be briefly paused by disconnecting the load and stopping the clock. One post of the weak cell should be disconnected from the rest of the battery and the cell bypassed with an appropriately sized jumper. A new final battery test voltage is calculated based upon the cells remaining under test. The test and timing can be resumed.

(5) Check each cell post and interconnection for overheating.

Table 6.
Discharge Current Correction Factor K for Temperature for Lead Storage Batteries

Initial Temperature (°C)	(°F)	Factor K
16.7	62	1.098
17.2	63	1.092
17.8	64	1.086
18.3	65	1.080
18.9	66	1.072
19.4	67	1.064
20.0	68	1.056
20.6	69	1.048
21.1	70	1.040
21.7	71	1.034
22.2	72	1.029
22.8	73	1.023
23.4	74	1.017
23.9	75	1.011
24.5	76	1.006
25.0	77	1.000
25.6	78	0.994
26.1	79	0.987
26.7	80	0.980
27.2	81	0.976
27.8	82	0.972
28.3	83	0.968
28.9	84	0.964
29.4	85	0.960
30.0	86	0.956
30.6	87	0.952
31.1	88	0.948
31.6	89	0.944
32.2	90	0.940
32.8	91	0.938
33.4	92	0.936

Note: This table is based on nominal 1.210 specific gravity cells. For cells with other specific gravities, refer to the manufacturer's instructions. Most manufacturers recommend battery testing be performed between 65°F and 90°F.

(6) When the test is completed, the capacity of each cell and of the entire battery can be calculated by the method described earlier.

Important: Recheck torque values and resistance readings of all electrical connections after a heavy and deep discharge. Disconnect the test system. Equalize the charge of the battery and return it to service. Do not delay in recharging the battery.

4.2.6 Integrity Testing. The integrity test effectively detects deficiencies in the battery bank's intercell connections. Loose or corroded connecting straps, bolts, or terminal posts impede high currents required of the battery during the integrity test. Voltage drops appear across cells or between cells. Poor connections also become noticeably warmer than properly cleaned and torqued connections.

The simplest way to conduct an integrity test is to disconnect the charger/rectifier and then measure battery cell and connection voltages under load. An artificial load is applied to perform the integrity test. The typical integrity test will take only a few minutes.

If convenient, perform thermographic scanning of the battery connections during an integrity test. This is an effective method to find poor intercell connections.

5. Uninterruptible Power Supply, Radio, and Other Special Application Battery Systems

At present, there are no specific IEEE or ANSI standards that cover uninterruptible power supply (UPS), radio, or other special application battery systems, testing or maintenance. However, after reviewing IEEE/ANSI 450-1987 and IEEE/ANSI 1106-1988, Western found that sections of these standards, coupled with manufacturer guidelines and gained experience, will provide the necessary information to develop and to establish an effective testing and maintenance program for such battery systems.

5.1 Installation. Upon delivery of each cell and prior to installation, each cell must be inspected carefully. The connectors and hardware must be counted and inspected. The installation should be supervised by someone knowledgeable in the detailed requirements.

After installation, the resistance of each connection is measured and recorded, using either a micro-ohmmeter or millivolt drop procedures, which put a measured direct current (10 to 100 milliamps) through the connection. The voltage drop is measured in millivolts, and that value is converted into micro-ohms of resistance. The average resistance of all the intercell connectors is determined by totaling the individual resistances and dividing by the number of connectors. In accordance with IEEE Standard 484, "Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations," each individual connector's resistance must not exceed the average by more than 10 percent. If any connection exceeds this value, it must be remade and remeasured, a new average taken, and the 10-percent limit rechecked.

After the battery is installed and the connectors meet the required standards, the initial equalizing charge, sometimes referred to as a battery forming charge, must be applied. The manufacturer's recommendations should be followed regarding the equalizing charge per cell for a given length of time. When the forming charge is complete, the total float voltage and the voltage of each individual cell are measured and recorded, along with the specific gravity of the electrolyte in each cell.

5.2 Battery Acceptance Test. In any new UPS battery installation, the UPS must go through a testing and shakedown process to identify possible system defects. When the UPS is fully operational, the entire charger (converter) battery/inverter system is given the following final test as a whole unit. A resistive load bank is connected to the UPS output to load it to its full kilowatt capacity at 1.0 power factor.

The battery is allowed to supply full power to the UPS and its load until either design time is reached (successful test) or the specified battery "end-of-line" voltage is reached (test failure), whichever occurs first. End-of-line voltage is about 1.67 to 1.63 volts per cell, and the UPS will usually have an automatic cutoff and shutdown at that input voltage.

The battery acceptance test is done at constant power load so that as the battery voltage drops, the current rises to maintain the power. In a typical 230-kilovolt-ampere installation, the initial current might be 760 amperes and could rise to 890 amperes at the end of the test. During the test, voltage and current are recorded continuously to document voltage and current profiles versus time at full load. These profiles should be compared to manufacturer's data to ensure conformance to specifications. Also, during the acceptance test, a thermal scan of the battery connections should be conducted (typical temperature rise should be about 10°C above ambient).

5.3 Maintenance

5.3.1 General. Proper maintenance will prolong the life of the battery system and will provide meaningful information for assuring that the battery system will be capable of satisfying its design requirements. An effective battery maintenance program will provide good information for determining the need for battery replacement. A summary of the recommended maintenance requirements is listed in table 7.

When a battery bank cannot be removed from service, a very cost-effective and extremely valuable performance test can be conducted. In the battery rundown test, the charger/rectifier is disconnected from the battery and the battery is forced to pick up the plant load for an extended period. Normally, this partial discharge is to a particular "final voltage," leaving sufficient capacity in the entire battery to permit it to carry its emergency load. The discharge data are logged and compared to the battery manufacturer's discharge curves.

Table 7.
Recommended Maintenance for UPS, Radio, and Other Typical Application Battery Systems

Recommended Maintenance Interval	Maintenance Requirements
Quarterly	1. Record the room temperature and examine the battery environment including the ventilating equipment. 2. Perform a detailed inspection of the battery system, including cells, racks, electrical connections, and grounding detector. Record and remedy such conditions as cracks, electrolyte leaks, post or connector corrosion or deposits, acid spills, and any other abnormal conditions. 3. Clean and/or eliminate any electrical ground leakage paths. 4. Clean intercell or intertier connectors and apply corrosion protection. 5. Measure and record the total float voltage and the voltage of the pilot cell. By measuring the pilot cell voltage, it serves as an indicator of battery condition between scheduled overall individual cell readings. 6. Check electrolyte level if applicable. 7. For lead-acid batteries, record the specific gravity of each cell, corrected to 77°F (25°C).
Annually	1. Perform the recommended quarterly routine items. 2. Measure and record the cell-to-cell resistance and inspect and rehabilitate all intercell and interior connections as required using the standards described in section 7.1 of this document. 3. Perform a battery rundown test at approximately 50 percent of the rated battery time, rather than 100 percent, unless there is a specific requirement to do otherwise. 4. If convenient, perform a thermographic survey of all intercell and intertier connections and disconnecting devices during the rundown test. 5. Return the battery to service and perform a recharge cycle. 6. Record the total bank float voltage and individual cell voltages.

5.3.2 Specific Maintenance Requirements

5.3.2.1 Quarterly Maintenance. Quarterly preventative maintenance is performed while the battery and UPS remain in service. The following checks are recommended:

(1) Record the room temperature and examine the battery environment, including ventilating equipment.

(2) Perform a detailed inspection of the battery system, including cells, racks, electrical connections, and grounding detector. Record and remedy such conditions as cracks, electrolyte leaks, post or connector corrosion or deposits, acid spills, and any other abnormal conditions.

(3) Clean or eliminate any electrical ground leakage paths.

(4) Clean intercell and interior connectors and apply corrosion protection.

(5) Measure and record the total float voltage and the voltage of each individual cell. (If the individual cell voltages vary by more than 0.05 volts from the average cell voltage, an equalizing charge is recommended. If only one or two cells deviate significantly from the average cell voltage, these cells should be examined carefully.)

(6) Check electrolyte levels.

(7) For lead-calcium batteries, record the specific gravity of each cell, corrected to 77°F (25°C).

5.3.2.2 Annual Maintenance. Since the annual maintenance requires disconnecting the battery system from the UPS system, this is the ideal time to shut down the entire UPS and do any testing and maintenance required in the rectifier/inverter systems. It is also the opportune time to test and maintain the backup generator and any other backup systems. Advance planning and coordination among all concerned groups are required so that downtime is kept to a minimum. The following are recommended:

(1) Perform the recommended quarterly routine items.

(2) Measure and record the cell-to-cell resistance; then inspect and rehabilitate all intercell and interior connections as required using the standards described in section 5.1.

(3 Perform a battery rundown test at approximately 50 percent of the rated battery time, rather than 100 percent, unless there is a specific requirement to do otherwise. This is considered sufficient to determine the actual capacity relative to its rated capacity, especially when the battery voltage and current readings are compared with the original benchmark data.

(4) Perform thermal scanning of all intercell and interior connections and disconnecting devices during the rundown test.

(5) Return the battery to service and begin the recharge cycle. Rerecord the total bank float voltage and individual cell voltages.

6. Replacement

6.1 Retirement. Generally, if the battery's capacity is below 80 percent of the rated capacity, the recommended action is replacement. The urgency of the replacement will depend upon the available capacity margin and the sizing criteria compared to normal load requirements. Whenever replacement is dictated, the maximum delay should be no more than 12 months. An 80-percent drop in capacity is evidence that the battery's rate of deterioration is increasing even if sufficient capacity remains to fulfill the needs of the load. Other criteria that may suggest battery or individual cell replacement follow:

- Significant differences in the capacities of individual cells in a battery may indicate replacement of selected cells is sufficient to maintain capacity.

- Unacceptable rundown test results for special application batteries can also dictate that replacement is necessary.

- Cell polarity reversal, failure to hold charge, and inability to maintain an acceptable specific gravity mandate further investigation and possible replacement of individual cells.

- As a battery approaches the end of its service life, it is not normally recommended that individual replacement cells be installed.

Note: Replacement cells must be compatible with the others remaining in the battery and should be discharge tested before installation.

6.2 Disposal. Unless tested and proven otherwise, electrolytes in both NiCad and lead-acid batteries are classified as hazardous waste. Recycling is the most cost-effective and trouble-free method of disposal, and therefore is the preferred method within Western for eliminating batteries when they are removed from service. The Resource Conservation and Recovery Act (RCRA) governs the requirements for management and control of all wastes, hazardous or non-hazardous, and applies to the disposal of batteries. RCRA states that spent batteries must be sent to a battery manufacturer for recycling or regeneration. Other recyclers are not acceptable. Some manufacturers will accept old batteries for recycling and regeneration. Although manufacturers generally accept lead-acid batteries more willingly than NiCad batteries, a fee may be charged for regeneration.

If all efforts to recycle used batteries fail, the batteries must be disposed of as a hazardous waste. The hazardous waste treatment or disposal facility must be fully permitted by Federal and local agencies. Hazardous wastes must also be shipped in accordance with Environmental Protection Agency, Department of Transportation, and local regulations. Shippers are also required to obtain permits for the transportation of hazardous materials. Western is responsible to ensure that contracted facilities and shippers hold the required permits. Western also has some responsibility for the observation and compliance of specific transportation requirements, even if a private carrier ships the battery cells.

Specific RCRA requirements that apply to the transportation and disposal of batteries may be obtained from Western's Division of Environmental Affairs, A0420.

7. References

Life Safety Code, NFPA 101-1981.

Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations, IEEE Standard 484-1987.

Recommended Practice for Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Generating Stations and Substations, ANSI/IEEE 450-1987.

Recommended Practice for Maintenance, Testing, and Replacement of Nickel-Cadmium Storage Batteries for Generating Stations and Substations, ANSI/IEEE Standard 1106-1987.

Recommended Practice for Sizing Large Lead Storage Batteries for Generating Stations and Substations, IEEE Standard 485-1983.

"Storage Battery Maintenance and Principles," **Power O&M Bulletin,** No. 12, U.S. Bureau of Reclamation, 1973.

Appendix A

Test Equipment

Appendix A

Test Equipment

The following equipment facilitates a complete storage battery testing program. These recommended pieces of equipment will test the capacity and integrity of lead-acid batteries, including the gel-type batteries and NiCad storage battery systems:

- Battery analyzer.

  A data acquisition and control unit used in conjunction with either a continuous load unit (CLU) or a momentary load unit (MLU). This unit tests up to 96 series connected batteries at currents up to 400 amperes.

- CLU.

  A constant-current resistive load bank. Testing with this device determines the battery capacity and detects any weak cells and faulty connections. The device tests at the following standard voltage ratings: 24 volts, 48 volts, 125 volts, 250 volts, and 430 volts. 15-kilowatt capacity.

- MLU.

  A short-term load (up to 25 seconds) is used to detect conduction path problems. The device tests at a current of 100 amperes at either 48 volts or 125 volts.

Appendix B

Forms

BATTERY DATA
LEAD STORAGE BATTERY

FACILITY ______________________ INSTALLATION DATE ______________________

TYPE (Check Type): Lead-Calcium ☐ Plante ☐ Lead-Antimony ☐

NUMBER OF CELLS ______________________

NOMINAL SPECIFIC GRAVITY AT 77°F ______________________

NORMAL FLOATING VOLTAGE AT 77°F ______________________

EQUALIZING VOLTAGE ______________________

RATED CAPACITY (AMPERE-HOURS) ______________________

PURCHASE DATE ______________________ MANUFACTURER ______________________

REPLACEMENT WATER—USE DISTILLED ONLY

BATTERY DATA
NICKEL CADMIUM STORAGE BATTERY

FACILITY ______________________________ INSTALLATION DATE ________________________

NUMBER OF CELLS ____

SPECIFIC GRAVITY AT 77°F ____

FLOATING CHARGE VOLTAGE ____

BOOSTER CHARGE VOLTAGE ____

RATED CAPACITY (AMPERE-HOURS) ____

ADD DISTILLED WATER AS REQUIRED TO MAINTAIN ELECTROLYTE LEVEL AS MARKED, OR HALFWAY BETWEEN THE PLATE TOPS AND THE INSIDE OF THE CONTAINER LID.

PURCHASE DATE ________________ MANUFACTURER _________________________________

SULFURIC ACID WILL RUIN THIS BATTERY

BATTERY MAINTENANCE REPORT
LEAD-ACID BATTERIES

FACILITY: ____

MONTHLY READINGS: ___________________________ PILOT CELL NO.: _____

Date	Air Temp	Battery Terminal Voltage	Charger Voltage	Charger Current	Pilot Cell Electrolyte Temp	Pil Cell Terminal Voltage	Pil Cell Specific Gravity	Recorded By

Cell No.	Term Volts	Specific Gravity	Cell No.	Term Volts	Specific Gravity	Cell No.	Term Volts	Specific Gravity	Cell No.	Term Volts	Specific Gravity
1			26			51			76		
2			27			52			77		
3			28			53			78		
4			29			54			79		
5			30			55			80		
6			31			56			81		
7			32			57			82		
8			33			58			83		
9			34			59			84		
10			35			60			85		
11			36			61			86		
12			37			62			87		
13			38			63			88		
14			39			64			89		
15			40			65			90		
16			41			66			91		
17			42			67			92		
18			43			68			93		
19			44			69			94		
20			45			70			95		
21			46			71			96		
22			47			72			97		
23			48			73			98		
24			49			74			99		
25			50			75			100		

QUARTERLY READINGS:

INTEGRITY TEST RESULTS: ____

REMARKS: ____

____

____

____

RECORDED BY: ____________________________________ DATE: __________

NICKEL-CADMIUM BATTERY MAINTENANCE REPORT

FACILITY: ______________________________ DATE: ____________________

Number of Cells: ____________ Type: ________________ Serial No.: __________

Purchase Date: ______________________ Installation Date: __________________

INDIVIDUAL CELL READINGS

CHARGER OUTPUT: ______________ Amps PANEL METER VOLTS: ____________

TOTAL BATTERY VOLTAGE: ______________ AIR TEMPERATURE: ____________°F

Cell No.	Volts	Cell No.	Volts	Cell No.	Volts	Cell No.	Volts	Cell No.	Volts

MONTHLY RECORD ____________________ PILOT CELL NO. ________________

Date	Pilot Cell Voltage	Battery Term Volts	Air Temp	Date	Pilot Cell Voltage	Battery Term Volts	Air Temp

REMARKS AND RECOMMENDATIONS: ____________________________________

READINGS TAKEN BY : ____